NEMI
National Electronics Manufacturing Initiative, Inc.

NEMI Lead Free Solder Efforts

Mark Kwoka Intersil Corp.

NEMI Lead Free Solder Efforts

- Tin Whisker Accelerated Test Task Group
- Tin Whisker User Group
- Tin Whisker Modeling Group
- Lead Free Assembly and Rework
- Lead Free Assembly – Completed
- RoHS Transition Task Group (new)
- Lead Free Wave Soldering (new)

www.nemi.org

NEMI National Electronics Manufacturing Initiative, Inc.

Whisker Test Standardization
ECTC 2004

Nhat (Nick) Vo

Objective: to develop industry standard test methods for predicting tin whiskers

Committee Structure

- Nick Vo (Chair) – Motorola/Freescale
- Jack McCullen (Co-Chair) – Intel
- Mark Kwoka (Co-Chair) – Intersil
- 48 companies including three governmental organizations

An open program (non-NEMI members welcome)

Whisker Test Standardization Team

agere
Agilent Technologies
hp
IBM
in
ON Semiconductor
ALCATEL
Allegro MicroSystems, Inc.
Infineon technologies
intel
Olin
PHILIPS
AMD
Amkor Technology
Raytheon
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FCI
FLEXTRONICS

- *ITRI Soldertec*
- *Micro Semi*
- *Soldering Tech.*

Connect with and Strengthen your Supply Chain

Whisker Test Standardization Status

Status:

- Phase 1 evaluation: Identify accelerated whisker test methods by evaluating various known test methods; completed
- Phase 2 evaluation: A factorial experiment looking for test methods involving Temperature, Humidity, and Thermal cycling; completed
- Submitted proposed test methods based on Phase 2 results, and inputs from JEITA and ITRI to JEDEC for survey ballot
- Phase 3 evaluation: Confirm Phase 2 results, determine whisker growth saturation to possibly define end points and assess mitigation techniques; underway
- Phase 4 evaluation: Verify voltage bias effects; just starting - boards and samples are being collected
- Phase 5 evaluation: Assess proposed test methods to other isothermal and thermal cycle conditions and possibly correlate to use condition

Phase 1 Evaluation Summary

- Samples (brass coupons and 8 lead SOICs) were prepared with bright Sn along with SnPb (control)
- Whiskers formed only on the bright Sn-plated coupons, and were few in number - much less than expected
- There were two possible explanations of low whiskering
  - the level of impurities and/or contamination were maintained very low (samples plated in the lab) and thus helped to retard whisker growth
  - when the terminations were formed the plating cracked reducing stress in the finish and thus helped to retard whisker growth
- The results of the Phase 1 study were inconclusive

Phase 2 Evaluation Parameters

- Finishes
  - Matte pure tin plated from MSA and Sulfate baths
  - 90Sn/10Pb alloy as a control
- Plating done on **production line** and in laboratory
- Samples
  - Production type components (OLIN 194 Cu SOIC)
  - Brass coupons (flat)
- Test Conditions (modified conditions from Phase 1)
  - Ambient exposure (30 C) for 5 months
  - Temperature + humidity storage (30C/90RH & 60C/95RH) for 4 weeks
  - Thermal cycling (500 cycles; -55C to 85C, 20 min cycle with 7 min dwell)
  - And a combination of all of the above conditions

Samples Tested in Phase 2 Evaluation

A: 2 to 3µm, Matte Sn (Sulphate) on OLIN194 Cu SOIC molded/singulated

B: 10 to 12µm, Matte Sn (Sulphate) on OLIN194 Cu SOIC molded/singulated

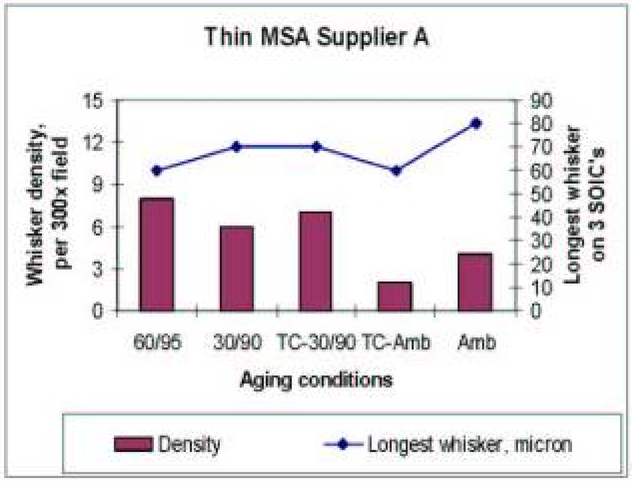
C: 2 to 3µm, Bright Sn on brass coupon

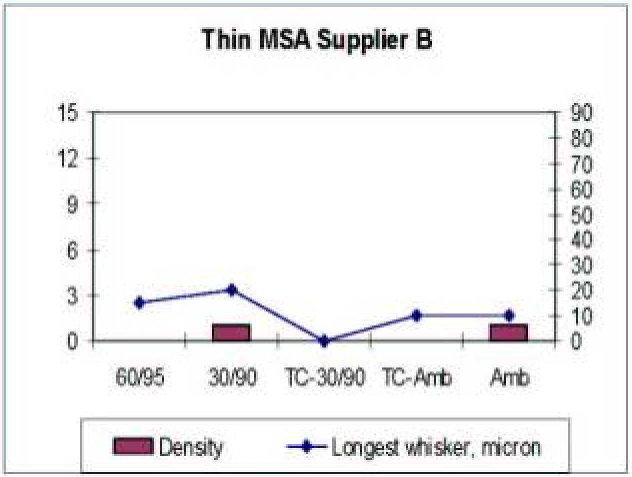
D: 10 to 12µm, 90Sn/10Pb on OLIN194 Cu SOIC molded/singulated (control)

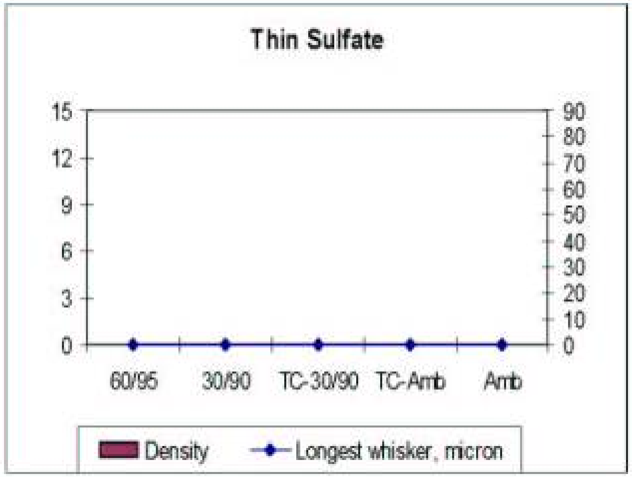
E: 2 to 3µm, Matte Sn (MSA) on OLIN194 Cu SOIC molded/singulated

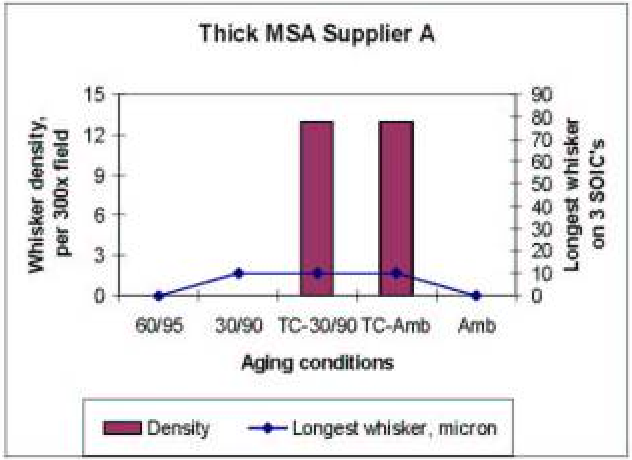
F: 10 to 12µm, Matte Sn (MSA) on OLIN194 Cu SOIC molded/singulated

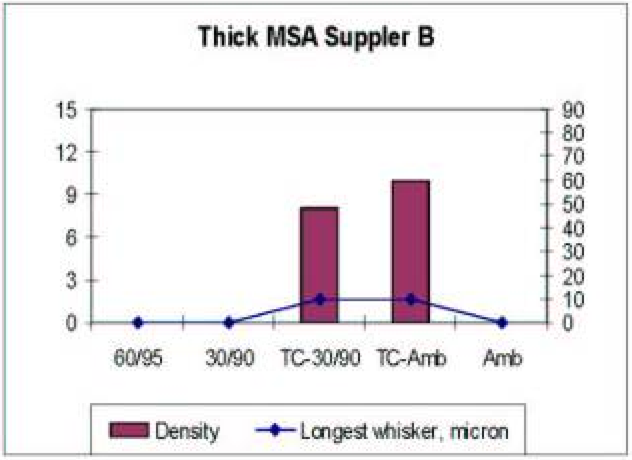
Phase 2: Effect of Bath Chemistry

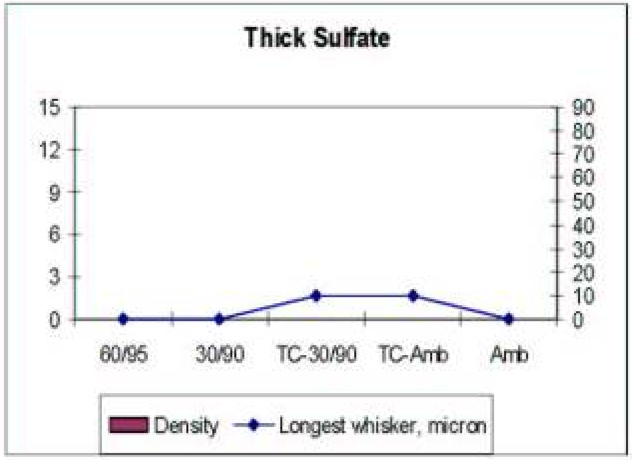












Phase 2 Evaluation Summary

- In general, more whiskers grew with the -55C/85C temperature cycle method, followed by 60C/90%RH storage; some whisker growth was also observed with the ambient environment
- There is no indication in this experiment that thicker deposits are less prone to whisker
- Bath chemistry/plating process parameters seem to have the most significant influence on whiskering
  - Slight advantage of sulfate-based chemistry comparing to a good-practice MSA bath
  - Significant difference between two MSA-based processes from two suppliers
- Whisker growth may be a multi-factorial phenomenon and the theory/model describing will need take into consideration numerous parameters

Recommended Test Method

Prepared whisker test method for release by JEDEC.

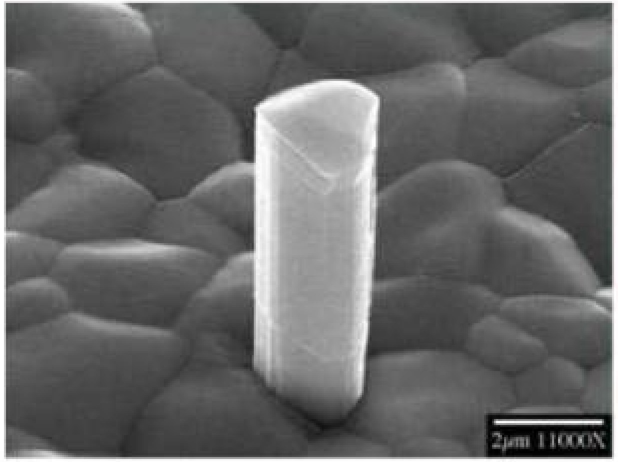
Purpose:

- **Provide test method to aid in the evaluation and development of plating finishes.**
- **Provide an industry-standardized test for comparison of whisker-propensity for different plating systems and processes.**
- **Not intended for use in reliability assessment or qualification.**

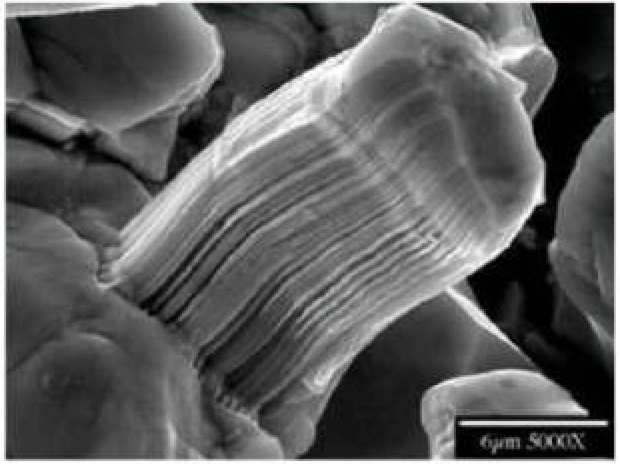
Recommended Test Methods:

- -55°C (+0, -10) / 85°C (+10, -0) air-air temperature cycle (20minutes/cycle)
- 60 + 5 °C, 93 +2, -3 % RH
- 20 - 25 °C, ~30-80% RH
- All three tests are to be performed using separate samples
- Each test condition is to be performed independently
- Arrived at methods in collaboration with JEITA and ITRI

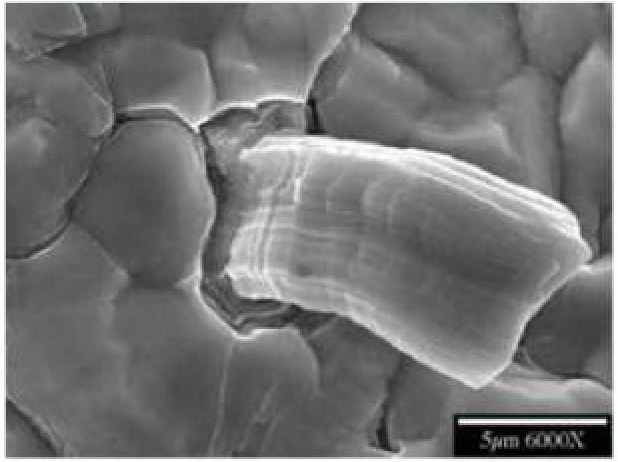
Whisker Examples



Consistent cross-section
(column)



Striations



Rings

Phase 3 Evaluation – Validate & Verify

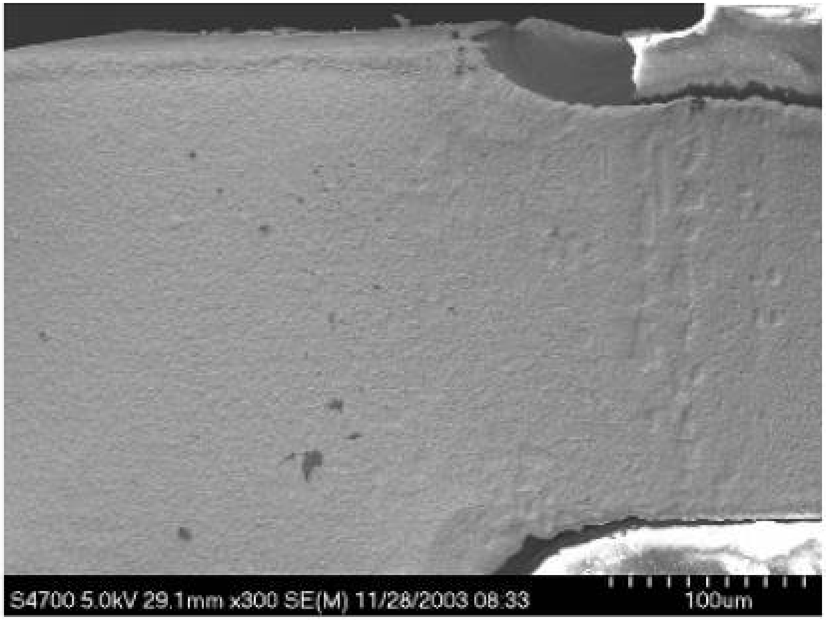
Tests:

- -55°C (+0, -10) / 85°C (+10, -0) air-air temperature cycle (20minutes/cycle) up to 3000 cycles (500 cycles check points)
- 60°C, 93±5%RH temperature / humidity storage 9000 hrs (~1 year) with 1000 hr check points
- Ambient storage (~23°C, ~60%RH) up to 18000 hours (~2 years) with 1000 hr check points

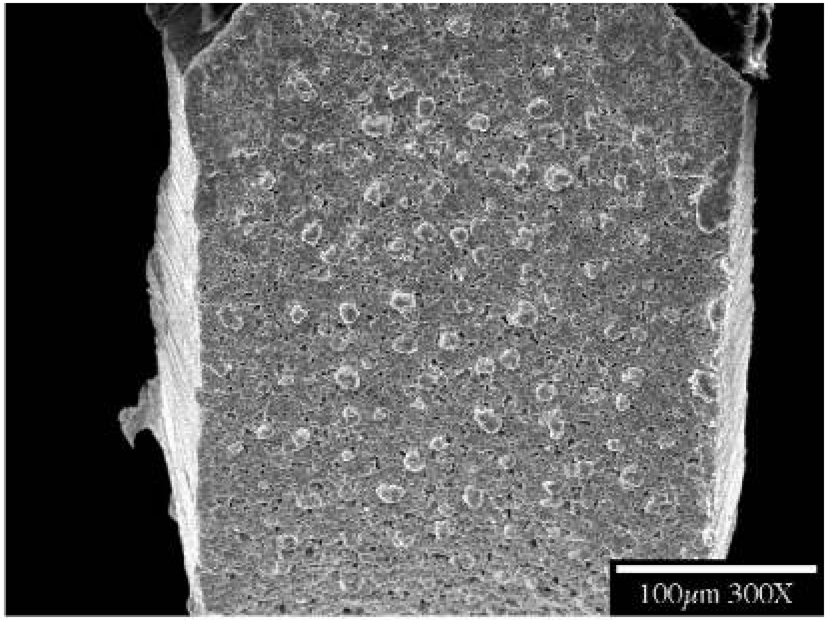
Samples:

- Leaded packages from production assembly sites
- Sn, SnBi, SnCu and SnAg finishes
- SnPb as control
- Copper CDA194, copper C7025 and Alloy42 leadframes
- For comparison include cells with
  - Matte Ni underplating
  - Fused (confirm melting) Sn
  - Post-plate baked Sn
  - Hot-dipped Sn
  - JEITA test vehicle

Phase 3 - SnPb Post-3000cyc SEM

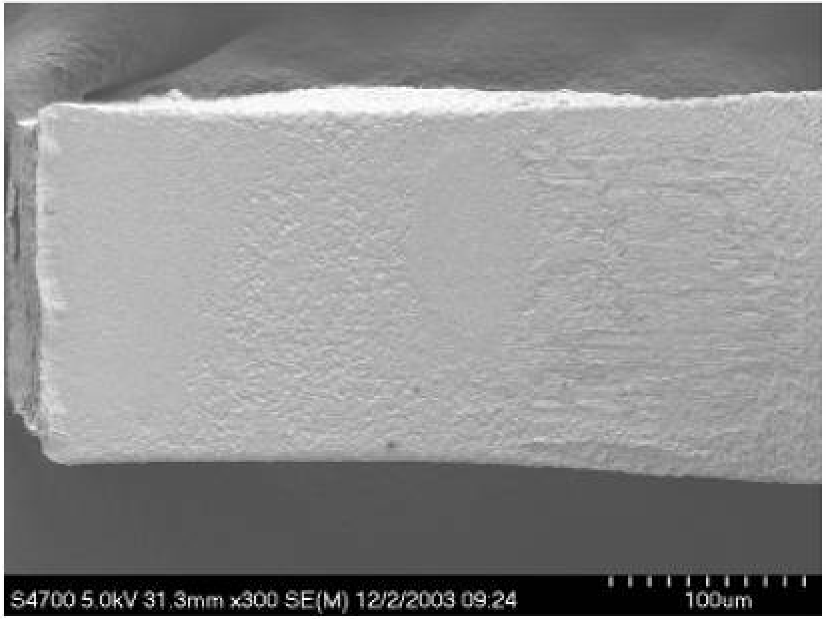


Cell 2, Sn/Pb, t_0 uncycled.

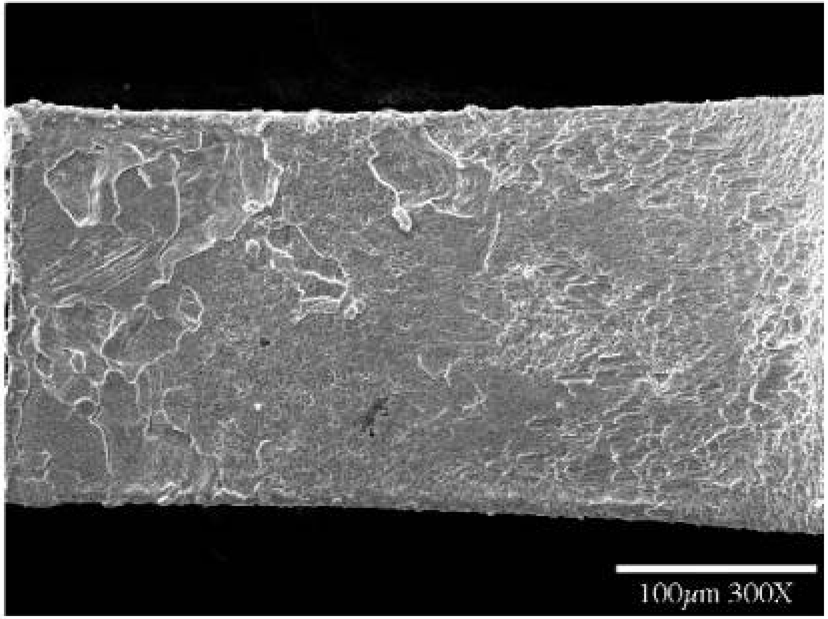


Cell 2, Sn/Pb, 3000 cycles.

Phase 3 - Matte Sn 3-5μm Post-3000cyc SEM

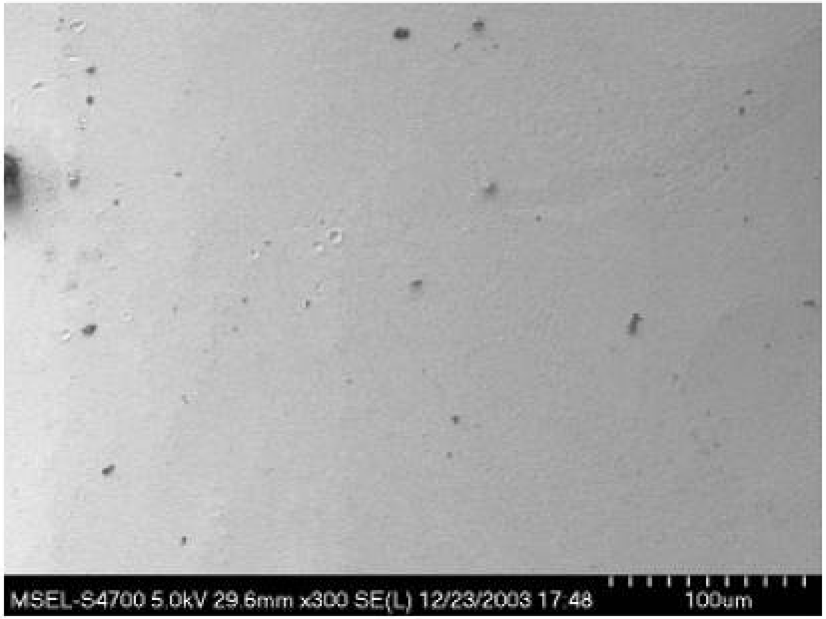


Cell 4, Matte Sn 3-5μm, t_0 uncycled.

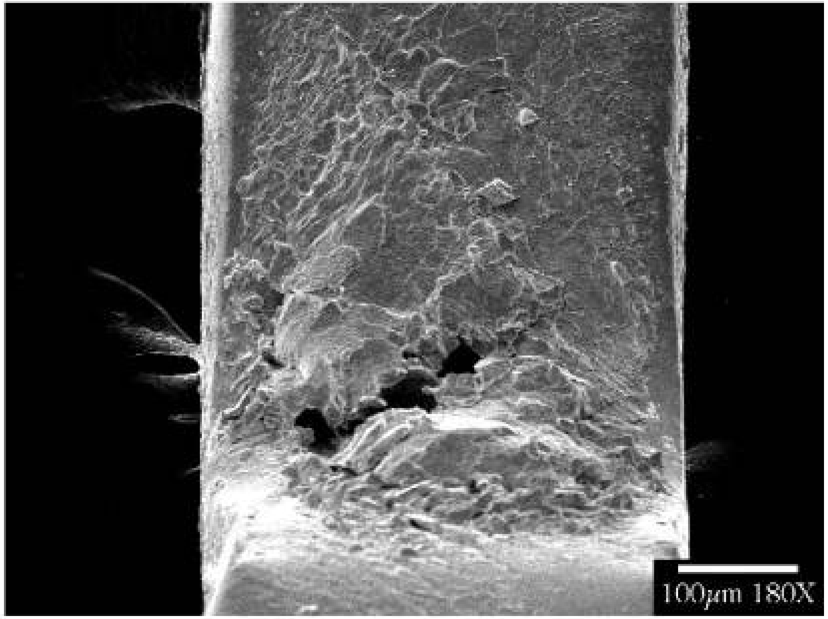


Cell 4, Matte Sn 3-5μm, 3000 cycles.

Phase 3 – Hot-dipped Sn Post-3000cyc SEM

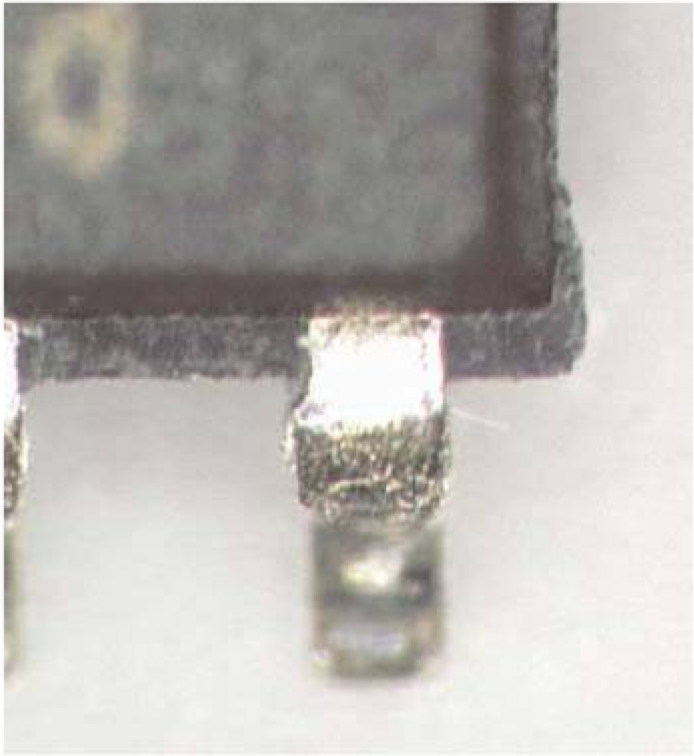


Cell 10, Hot Dipped Sn, t_0 uncycled.

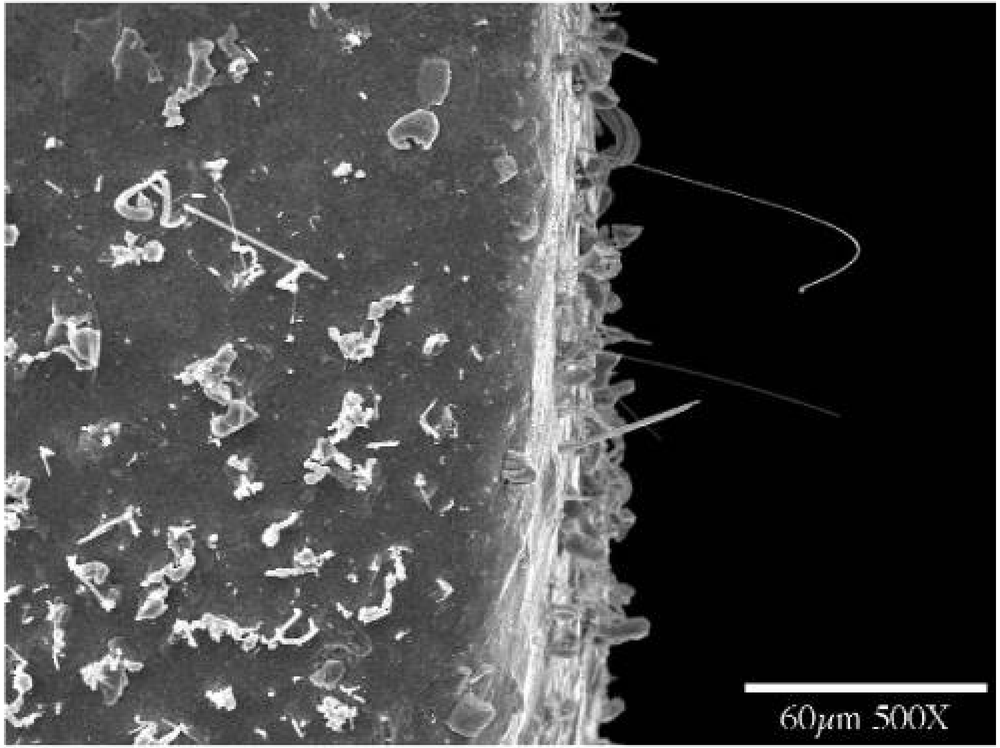


Cell 10, Hot Dipped Sn, 3000 cycles.

Phase 3 – Hot-dipped Sn Post-3000cyc SEM

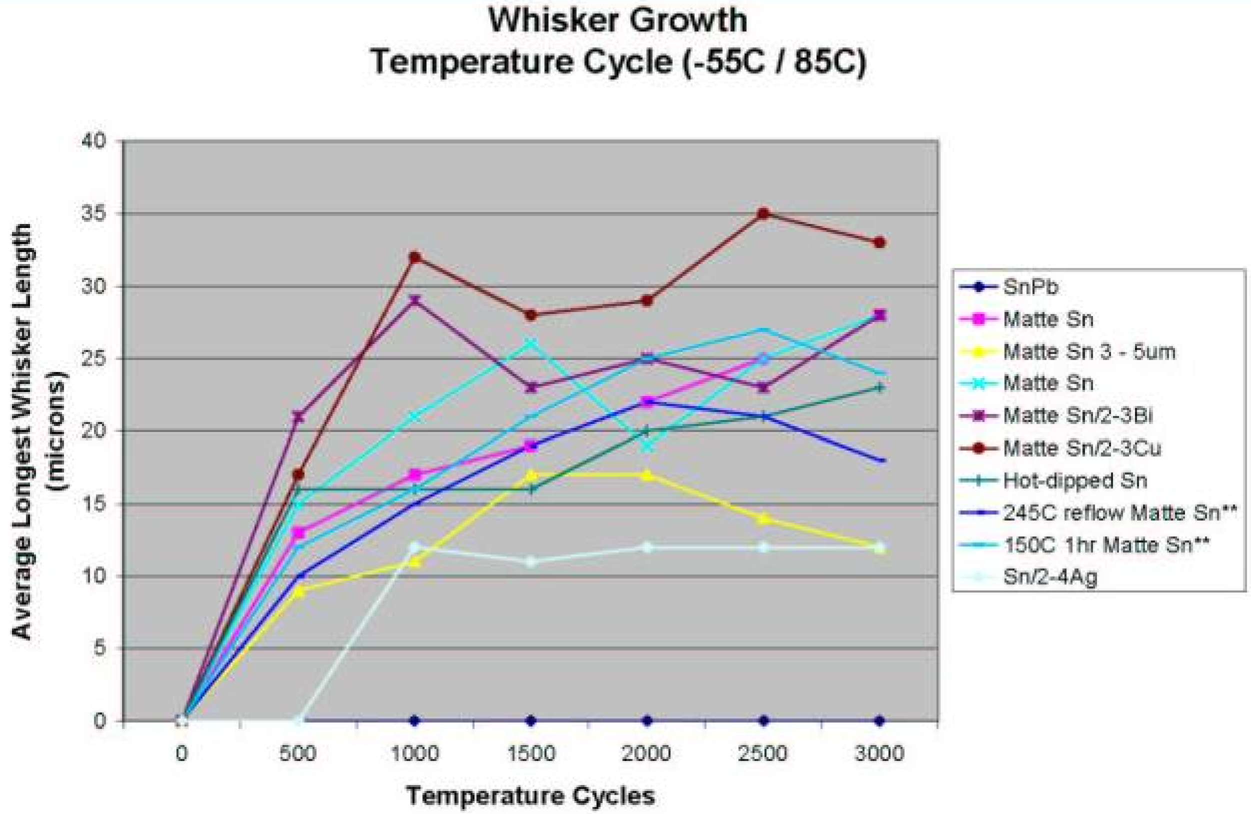


Cell 10 Hot Dipped Sn
Optical image



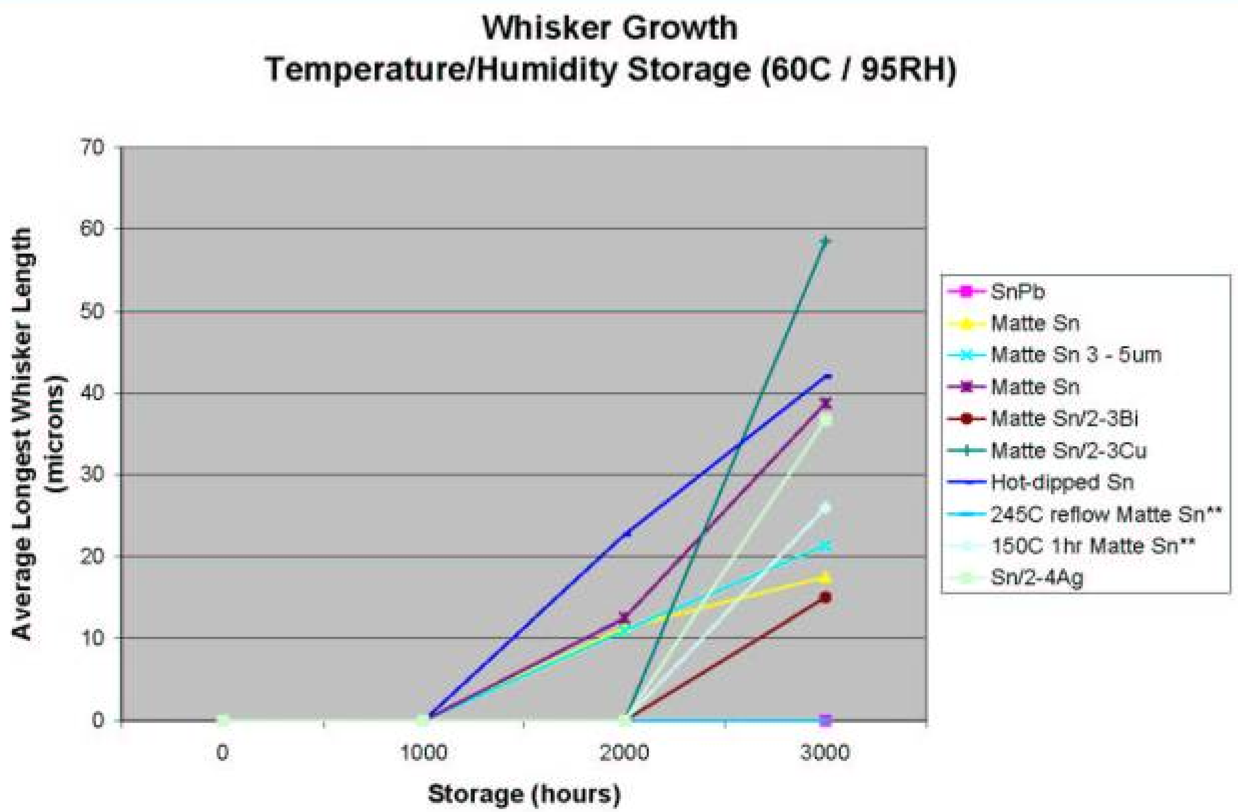
Cell 10 Hot Dipped Sn same lead as at left.

Phase 3 – Thermal Cycle Results



- Whiskers formed as soon as 500cycles
- Between 1000 and 1500 cycles whisker growth appears to saturate
- Grain growth and coarsening is easily observable at 3000cycles

Phase 3 – Isothermal Storage Results



- Whiskers formed as soon as 2000hours
- Different incubation periods for each finish
- Corrosion products is observed at 3000hours for some cells
- Not all leads whisker (such as the case with SnAg)

Phase 3 – Summary

- *Test methods are showing repeatability*
- *Thermal cycle whisker growth appears to saturate around 1500cycles*
- *Component construction effects longest whisker length observed in thermal cycle testing*
- *Additional analysis on-going for thermal cycle data*
- *Incubation period is different for different plating types in isothermal storage*
- *Plating finishes respond differently between test methods (150C baked Sn, SnAg samples)*
- *Isothermal and ambient storage is on-going*

NEMI National Electronics Manufacturing Initiative, Inc.

NEMI Tin Whisker User Group

Tin Whisker Acceptance Test Requirements
(Updated July 28, 2004)

Joe Smetana, Alcatel, Chairman

The NEMI Tin Whisker User Group
Active Participants

Participant companies provide products in Automotive, Consumer, High-End Computing, Space, & Telecom Industries

• Joe Smetana	Alcatel - Chairman
• Rick Charbonneau	Formerly of Storage Tek
• Vicki Chin, Zequn Mei, Diana Chiang	Cisco
• Richard Coyle	Lucent - Co-Chairman
• George Galyon	IBM eSystems Group
• Ron Gedney	NEMI consultant
• Bob Hilty	Tyco Electronics
• John Lau	Agilent Technolgies
• Sean McDermott	Celestica
• Rich Parker	Delphi Electronics & Safety
• Frances Planinsek	Storage Tek
• Heidi Reynolds & David Love	Sun Microsystems
• Valeska Schroeder, Elizabeth Bennedeto	Hewlett Packard

Also

Nick Vo of Freescale represents the supplier point of view

Tin Whisker Mitigation Requirements

- Components qualified and accepted by this testing <u>shall</u> utilize one of the preferred mitigation practices specified in “Tin Whiskers, NEMI Users Group Position statement” (available at www.nemi.org), briefly summarized:
  - Fusing by the component supplier of the tin plating within a short time frame after plating.
  - Use of a hot dip tin (or tin alloy) finish rather than plating.
    - » Hot dip SnAgCu is the preferred alloy.
  - Use of nickel plated barrier layer between the base material and the tin
  - Annealing/heat treating (150°C for 1 hour) of a matte tin finish within a short time frame after plating (typically less than 24 hours).
    - » Note: This mitigation practice may not be acceptable to all users.
  - Other acceptable mitigation practice as defined by the User Group Position Statement section III, paragraph 15

Overview of Testing

- 3 Test Segments: 2 isothermal and 1 Temperature Cycling of NEMI "Tin Whisker Growth Test" (Submitted to JEDEC)
  - Ambient/Storage (30ºC, 60% RH)–minimum* 4000 Hrs
  - Aging/Temperature & Humidity (60ºC, 93%RH)–minimum* 4000 Hrs
  - Thermal Cycling (-55ºC to + 85ºC)–minimum* 1000 cycles

    * Test Durations may be longer depending on results (more later)
- Tests are extended to include assembly preconditioning and bias to represent actual use conditions

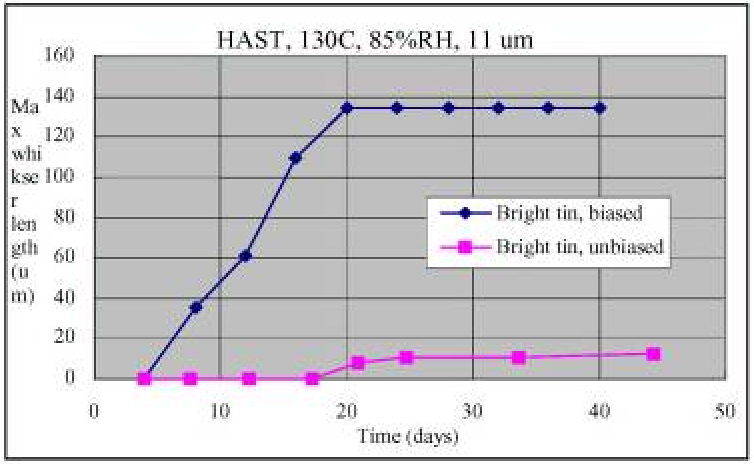
Sample Size – Test Components

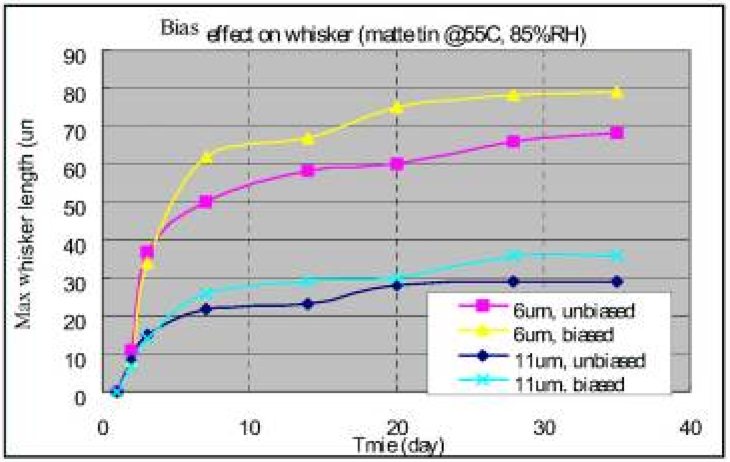
Each lot - a different date code & plated at least one week apart

# Components (leads)/Lot (minimum)[1]	# Lots	Precondition[3]	Test Condition	Total # Components (leads) (minimum)
3 (30)	3	4 weeks @ room temperature (RT)	Storage – No Bias	9 (90)
3 (30)	3	4 weeks RT	Aging – No Bias	9 (90)
3 (30)	3	4 weeks RT, then Assembly Sim @ 215°C	Storage – No Bias	9 (90) [3]
3 (30)	3	4 weeks RT, then Reflow @ 255°C	Storage – No Bias	9 (90) [3]
3 (30)	3	4 weeks RT, then Assembly Sim @ 215°C	Aging – No Bias	9 (90) [3]
3 (30)	3	4 weeks RT, then Reflow @ 255°C	Aging – No Bias	9 (90) [3]
3 (30)	3	4 weeks RT, then Assembly Sim @ 215°C	Thermal Cycle – No Bias	9 (90)
3 (30)	3	4 weeks RT, then Reflow @ 255°C	Thermal Cycle – No Bias	9 (90) [3]
3 (30)	3	4 weeks RT, then Assembly @ 215°C	Storage – Bias	9 (90) [2] [3] [4]
			Total Components Required	**81 (810)**

Bias Testing

- **Bias effect on Tin Whisker Growth appears to be finish dependent**
  - **Our primary goal is to test whether or not whisker growth on the finish being qualified is affected by bias or not.**
  - **As such we've limited the testing to ambient samples only.**
  - **Examples: #1 Phillips data**



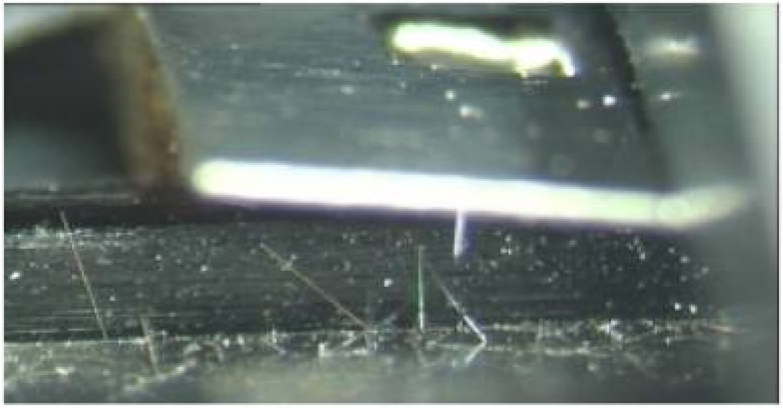


Clear effect on Bright Tin, Matte Tin Data not conclusive

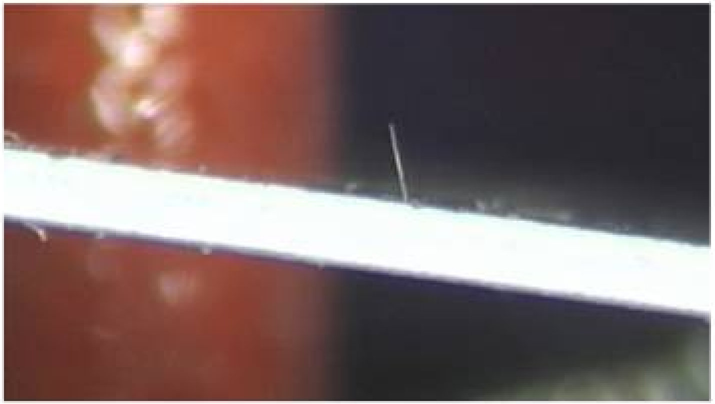
(Philips statement: "no effect")

Bias Testing (continued)

- **Example 2: TI Application Report SZZA037 - January 2003 (Tests on Matte Tin)**
  - **"we found whiskers quite consistently on the biased samples, but not on the parallel run of parts with no bias"**
- **Example 3: Alcatel Field Failure on Bright Tin Plated Breaker (50V Bias)** **(Tin should have been reflowed – but was not)**



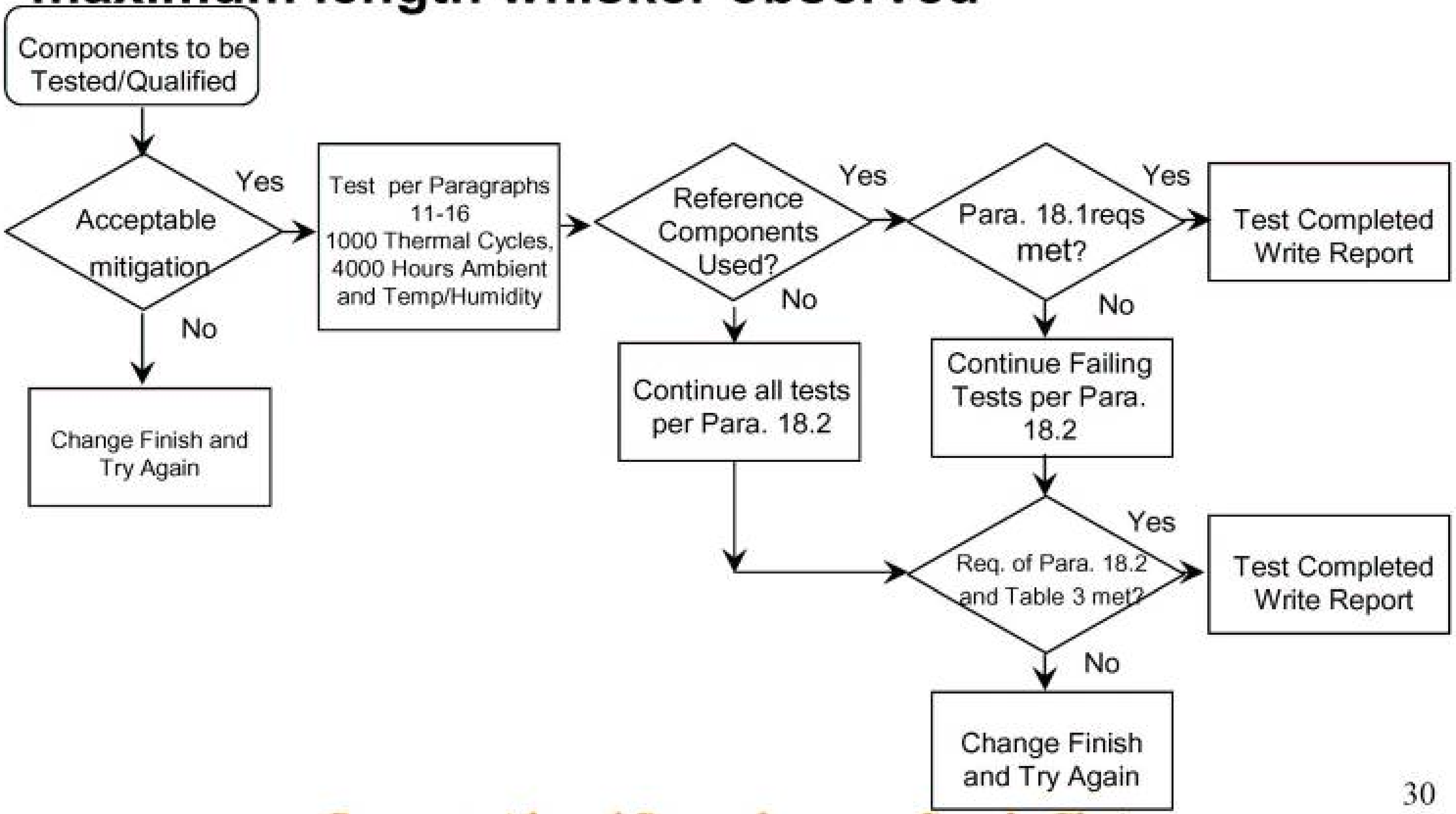
Whiskers in Bias Area – Dense and 2-5 mm long!



Whiskers away from Bias Area – Much Fewer and a max of about 1mm long

Acceptance Requirements

- **Whisker acceptance requirements are based on the maximum length whisker observed**



Acceptance Requirements (continued)

- **Tested Finish after 1000 T/C, 4000 Hours Storage (Ambient), 4000 Hours Aging (Temp/Humidity)**
  - Whisker Length = SnPb Reference (or better)
    - » Done – Tests pass
  - If any tests fail to = SnPb Reference or if SnPb Reference components not used, must be continued (failing tests only)
    - » T/C test – minimum of 2000 cycles or 3 consecutive measurements at 500 cycle intervals show no growth
    - » Storage and/or Aging test – minimum of 5000 hours or 3 consecutive measurements at 1000 hour intervals show no growth
      - If you can't inspect the same whiskers – increase the sample sizes to show statistical significance!
    - » Must meet the Maximum Whisker Length Requirements - following

Max Length Without a Short Circuit

- **Worst case, this is equal to ½ the distance from a lead to another lead or lead on another component or 1X the distance to the nearest trace on the PCB.**
  - An excerpt from the Appendix B table:

Device Pitch	Typical Minimum gap between leads(1)	Maximum allowable whisker length in application (=1/2 min typical gap)	Maximum allowable whisker length in testing (safety factor = 2/3 maximum distance)	Maximum allowable whisker length in testing (safety factor = ½ maximum distance)
Discrete Device (2 pin)	200 µm	100 µm	67 µm	50 µm
0.65 mm to < 1.27 mm	150-200 µm (2) (JEDEC MS-204)	75 – 100 µm	51 – 67 µm	38-50 µm
0.5mm to < 0.65 mm	125–150 µm (2) (JEDEC MS-204)	63 -75 µm	42-51 µm	32-38 µm
0.4mm to < 0.5mm	120 µm (2) (JEDEC MO-194B)	60 µm	40 µm	30 µm

Below our requirements…

Class Definitions

- The company purchasing components will classify its products. Below are general guidelines for product classes. However, these guidelines may not apply in all cases.
  - Class 1
    - » Mission/Life Critical High Reliability Applications such as military, space and medical applications
      - Pure tin and high tin content alloys not acceptable
  - Class 2
    - » High Reliability Business Applications such as Telecom Infrastructure equipment, High-end Servers, etc.
      - Long product lifetimes and minimal downtime
      - Products such as disc drives typically fall into this category
      - Breaking off of a tin-whisker is a concern
  - Class 3
    - » Consumer Products
      - Short product lifetimes.
      - No major concerns with tin whiskers breaking off

Whisker Length Limits

<table>
<tr><th colspan="4">Maximum Whisker Length</th></tr>
<tr><th>Device Considerations
(Package type, lead pitch or operating frequency)</th><th>Class 1</th><th>Class 2</th><th>Class 3</th></tr>
<tr><td>Discrete Device (2 pins)</td><td rowspan="3">Pure tin and high tin content alloys not acceptable.</td><td rowspan="3">40 µm</td><td>67 µm (1)</td></tr>
<tr><td>Multi-lead packages</td><td>(Minimum gap between leads - .05mm)/3 or 67 µm, whichever is smaller(1)(2)(3)</td></tr>
<tr><td>Operating Frequency > 6GHz (RF)(4) or t_{rise} < 59 psec (digital)</td><td>50 µm</td></tr>
</table>

(1) Often must also meet high frequency/high speed requirements
(2) Spacing does not account for dam bar protrusion, a risk area
(3) Accounts for up to 0.05mm bent leads. Max of 67µm accounts for adjacent discrete devices.
(4) Degradation associated with tin whiskers increases with frequency. The maximum frequency analyzed was 20GHz.

Safety Factor

- Based on all the previous, the User Group chose the following safety factors for test data relative to field data
  - Class 3: Maximum allowed whisker = 2/3 Worst case situation
  - Class 2: Maximum allowed whisker = ½ Worst case situation
    - » Note – rounded up from 37.5 to 40µm for ½ RF concerns
    - » Also compromised on 0.4 mm pitch devices

Process Controls and Periodic Testing

- We are convinced that repeatability of the process is one of the key items that affect tin whisker propensity of a finish
  - Suppliers must define and maintain plating process controls
  - Some specifics that Users require
    - » Carbon content shall be kept below 0.05%
    - » Copper content (except for SnCu alloys) should be kept below 0.5%
  - Characteristics of the tin plating shall also be determined and controlled

Ongoing Tin Whisker Monitoring

- **Supplier will establish a system to periodically monitor the performance of the processes for whisker generation. The specifics of this system are left to the supplier however the following minimum guidelines are suggested.**
  - A representative sample of components should be taken for each designated time period
  - The time period for these samples should be at least monthly
  - The storage conditions for these components should include a relative humidity of 60% or greater. Using the ambient test conditions of reference 3.2 (Tin Whisker Test) is preferred.
  - The samples should be inspected for whiskers 6 months from the date of plating.
  - Results should be compared to baseline measurements. If these are exceeded, supplier should take appropriate corrective actions.